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## HEMOGLOBIN IS AN ALLOSTERIC PROTEIN

The $\alpha$ and $\beta$ subunits of hemoglobin have the same structural design as myoglobin. However, new properties of profound biological importance emerge when different subunits come together to form a tetramer. Hemoglobin is a much more intricate and sentient molecule than is myoglobin. Hemoglobin transports $H^+$ and $CO_2$ in addition to $O_2$. Furthermore, the oxygen-binding properties of hemoglobin are regulated by interactions between separate, nonadjacent sites. Hemoglobin is an allosteric protein, whereas myoglobin is not. This difference is expressed in three ways:

1. The binding of $O_2$ to hemoglobin enhances the binding of additional $O_2$ to the same hemoglobin molecule. In other words, $O_2$ binds cooperatively to hemoglobin. In contrast, the binding of $O_2$ to myoglobin is not cooperative.

2. The affinity of hemoglobin for oxygen depends on pH, whereas that of myoglobin is independent of pH. The $CO_2$ molecule also affects the oxygen-binding characteristics of hemoglobin.

3. The oxygen affinity of hemoglobin is further regulated by organic phosphates such as 2,3-bisphosphoglycerate (BPG). The result is that hemoglobin has a lower affinity for oxygen than does myoglobin.

*Torr*—
A unit of pressure equal to that exerted by a column of mercury 1 mm high at 0°C and standard gravity (1 mm Hg).
Named after Evangelista Torricelli (1608–1647), the inventor of the mercury barometer.

## OXYGEN BINDS COOPERATIVELY TO HEMOGLOBIN

The saturation $Y$ is defined as the fractional occupancy of the oxygen-binding sites. The value of $Y$ can range from 0 (all sites empty) to 1 (all sites filled). A plot of $Y$ versus $pO_2$, the partial pressure of oxygen, is called an *oxygen dissociation curve*. The oxygen dissociation curves of myoglobin and hemoglobin differ in two ways (Figures 7-21 and 7-22). For any given $pO_2$, $Y$ is higher for myoglobin than for hemoglobin. This means that *myoglobin has a higher affinity for oxygen than does hemoglobin.* Oxygen affinity can be characterized by a quantity called $P_{50}$, which is the partial pressure of oxygen at which 50% of sites are filled (i.e., at which $Y = 0.5$). For myoglobin, $P_{50}$ is typically 1 torr, whereas for hemoglobin, $P_{50}$ is 26 torrs.

The second difference is that *the oxygen dissociation curve of myoglobin is hyperbolic, whereas that of hemoglobin is sigmoidal.* Let us consider these curves in quantitative terms, starting with the one for myoglobin be-

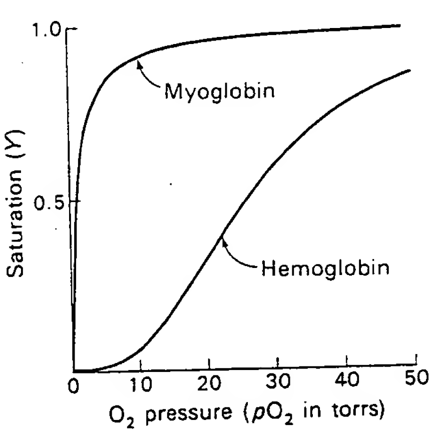


**Figure 7-21**
Oxygen dissociation curves of myoglobin and hemoglobin. Saturation of the oxygen-binding sites is plotted as a function of the partial pressure of oxygen surrounding the solution.

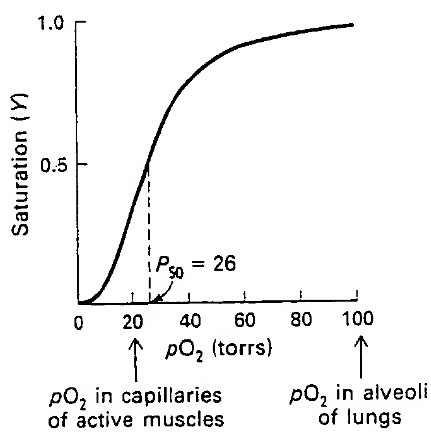


**Figure 7-22**
Oxygen dissociation curve of hemoglobin. Typical values for $pO_2$ in the capillaries of active muscle and in the alveoli of the lung are marked on the horizontal axis. Note that $P_{50}$ for hemoglobin under physiological conditions lies between these values.